

On Changes which are found with Advancing Age in the Calcareous Deposits of *Stichopus japonicus*, Selenka.

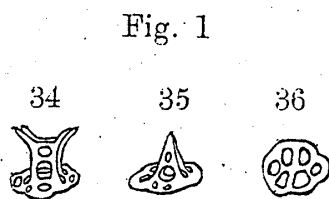
By K. Mitsukuri, Ph. D.

Professor of Zoology, Imp. Univ., Tokyo.

I am at present engaged in a study of the Holothurioidea of Japan, the results of which I hope to publish elsewhere before long. But the following facts in regard to the calcareous bodies of our commonest holothurian—*Stichopus japonicus*, Selenka,—appear to me remarkable enough to deserve a separate preliminary notice.

The statements made by previous writers about the calcareous bodies of that species do not in many respects agree with one another, and it will be found difficult to obtain from them a clear idea on the matter. This is not to be wondered at, as some most important facts have hitherto been entirely overlooked.

SELENKA who gave the first description of the species (*Zeitsch. für wiss. Zool.*, Bd. XVII, p. 318) had only one specimen 110 mm. long. In



Calcareous bodies of
Stichopus japonicus. Copied
from SELENKA.

regard to the calcareous bodies, he says ;
“*Die Kalkgebilde bestehen ausschliesslich in 0.05mm. breiten thurmformigen Körper (Fig. 34–35), unter denen ich sehr zahlreiche Hemmungsbildungen, nämlich durchbrochene Ringe, finde (Fig. 36).*”

VON MARENZELLER who next touched on the subject (“*Neue Holothurien von Japan und China*,” *Verhandl. zoolog-bot. Gesellsch. Wien*, 1881, p. 137) had several specimens, the largest of which was 70 mm. long and not sexually ripe. He says:—
“*Die Kalkkörper sind, wie SELENKA angiebt, von den Kalkstäben der*

Füsschen abgesehen, nur einerlei Art. Die Fig. 35 (SELENKA, *l. c.*) gibt wohl nur eine Hemmungsbildung wieder, die dadurch entstanden, dass die Stäbchen des Stieles nicht gleichmässig zur Ausbildung kommen, und mit einander vor der Bildung einer Krone verschmelzen. Uebrigens habe ich eine solche Form nie gesehen. Fig. 11a* stellt eine regelmässige kleine, Fig. 11b* eine grosse Scheibe dar. Die Scheibe der Stühlchen misst in Durchmesser nicht leicht unter 0.045 mm. und selten 0.075 mm. Dazwischen alle Grössen. Ich finde den Stiel nicht durchaus so gebildet, wie ihn SELENKA unter Fig. 34 wiedergibt. Er ist hier breit und zeigt nur einen einzigen Querstab unter der Krone, deren Zacken übrigens zu stark nach aussen gebogen scheinen. Neben solchen Stühlchen, an welchen der an der Basis z. B. 0.18 mm. breite und 0.033 mm. hohe Stiel gegen das Ende immer verbreitert ist, finden sich andere noch von gleicher Gestalt, aber mit zwei Querstäben im längeren Stiele, und dann durch Uebergänge verbunden solche, deren Stiel schmal, lang, mit zwei und mehr Querstäben versehen und etwas konisch zulaufend, nicht verbreitert ist. * * * * Ferner kann die Zahl der Stäbchen des Stieles reducirt werden. Ich fand ein Stühlchen mit einem 0.09 mm. langen und 0.015 mm. breiten Stiele, der fünf Quertäbe aufwies, aber aus nur zwei Langsstäben bestand." No mention is made by v. MARENZELLER of the presence of such perforated plates as are given in SELENKA's fig. 36.

THÉEL in his Report on the Challenger Holothurioidea (Reports, vol. XIV) had one specimen of *Stichopus japonicus*, and says: "The specimen does not quite agree with the description of SELENKA and VON MARENZELLER, but nevertheless, I do not think it possible to refer it to any other species. * * * * It is especially with regard to the deposits that disagreements exist, which render the correctness of my determination dubious. The tables have the same shape as described by VON MARENZELLER (Pl. VII., fig. 3, a, b.) but, besides these, I find a great quantity of small rounded or oval perforated plates (Pl.

* VON MARENZELLER's figs. 11 a and b are very much like Fig. 2 a, b, of the present article.

VII, fig. 3, c), some of which bear a certain resemblance to buttons. SELENKA also described such bodies under the name of 'Hemmungsbildungen'."

THÉEL had two other specimens each 220 mm. long which he established into a new variety under the name of *Stichopus japonicus*, var. *typicus*. In regard to the calcareous bodies of these specimens, he found that they consisted of tables alone, but comparatively few of them were fully developed, by far the greater part presenting themselves under the shape of perforated discs with the margin very uneven or spinous, and with no spire or a very poorly developed one. The rare complete tables were smaller and larger, composed of a rounded perforated disc with smooth margin and a spire built up of mostly four rods, with one or more transverse beams, and often terminating in four longer or shorter teeth. There were also found tables with a spire composed of only two rods. It is but just to THÉEL to mention that he makes a distinct statement to the effect that, these specimens may prove to be older and more developed forms of *Stichopus japonicus* than those previously studied.

LAMPERT in his "Die Seewalzen" says: "Stiel der Stühlchen bald mit einer, bald mit zwei Querleisten, in letztem Falle oft mit seitlichen Dornen besetzt; die als durchbrochene Ringe erscheinenden Hemmungsbildungen sehr zahlreich." He also says "einspitzige Stühlchen wie SELENKA eines abbildet, konnte ich eben so wenig wie v. MARENZELLER auffinden."

To make the matter still more intricate, the form which SELENKA (*l. c.*) described under the name of *Holothuria armata* and in which he found only sparingly "durchbrochene Plättchen" besides the "Endscheiben," is considered by THÉEL to be probably nothing else than *Stichopus japonicus* (Challenger Report, Vol. XIV, p. 196).

From these citations, we are able to gather the fact that the calcareous deposits of *Stichopus japonicus* consist of only one kind, viz. tables. But beyond this, it is difficult to obtain any clear ideas. It is most probable that these tables are present in the shape of simple per-

forated plates as "Hemmungsbildungen," but VON MARENZELLER makes no mention of them. As to what the shape of the complete tables is, one will be sorely puzzled to find out. The figures and descriptions given by SELENKA and by LAMPERT will be found difficult to reconcile with those of VON MARENZELLER or of THÉEL. Moreover, while it seems certain that there are forms closely related to *Stichopus japonicus*, such, for instance, as that described by THÉEL as var. *typicus*, or that called by SELENKA *Holothuria* (or *Stichopus* according to THÉEL) *armata*, it is impossible to know exactly in what relation these forms stand to the species proper or to one another.

When I began to examine the specimens of what I supposed to be *Stichopus japonicus* my perplexity was greatly increased. For actual specimens seemed to be about as varied as the descriptions of the above mentioned authors. Individual after individual were found with only perforated plates * and without any complete tables. Or if I succeeded in finding some with complete tables, these latter seemed to show a great variety of forms among themselves, so that it was impossible to specify a shape common to all specimens. Finally, the question seemed to resolve itself into this: Either there are two distinct species among the form known in Japan as the common "namako" (hitherto supposed to be identical with *Stichopus japonicus*), one species corresponding to *Holothuria armata* of SELENKA and the other to *Stichopus japonicus* of the same author, or else the species known as *Stichopus japonicus*, Selenka, presents an extraordinary variety of forms in their calcareous deposits. If the former alternative was the case, it was most desirable to establish the fact and to define the limits of each species, for it had a most practical bearing on the question which it had been, and is, my purpose to study, viz. how to protect or cultivate the *namako* for economic purposes. If the latter alternative was the case, it would be of great morphological interest to find out with what conditions, these variations of the calcareous deposits are correlated. To settle the ques-

* Apart from the terminal disc and supporting bodies of the tube-feet and papillæ. Of these, I am not at all speaking in the present article.

tion in either way, the overhauling of a large number of specimens of both sexes, at various stages of growth and from all sorts of localities was a necessity. Fortunately, I had been slowly accumulating just such a collection, in course of the inquiry undertaken with the above-mentioned economic object at the request of the Ministry of Agriculture and Commerce. Moreover, from the experience thus gained, I found it possible to tell within certain limits the age of a given "namako" and obtained the knowledge of when and where individuals of certain sizes might be found.* I thus flattered myself that I had favorable opportunities for settling the question put forth above in regard to the calcareous deposits of the "namako."

I shall now briefly set forth the results of my study on this question:—

The holothurians commonly known in Japan under the name of the "namako" all belong to one species, viz.:—*Stichopus japonicus*, Selenka. The form distinguished by THÉEL as var. *typicus* is only a stage in the growth of the species. *Holothuria armata*, Selenka may possibly be better set down as a variety of this species, *not*, indeed, on account of its calcareous deposits but of some other characters—as will become clear in the sequel.

The form of calcareous bodies † changes with advancing age in Stichopus japonicus. The youngest individuals have most perfectly formed, large-sized tables and nothing but these. They have such tables very thickly crowded or even overlapping with their bases. With the growth of the animal, perfectly formed tables decrease both in number and size, and tables in various stages of arrested development are found mixed with them. The degree of imperfection in tables of arrested development as well as the proportion of such tables to perfectly formed ones constantly increase with age,

* It is my intention to put together elsewhere the results of my inquiry into the habits and life-history of the "namako," together with my plan for the propagation of the animal.

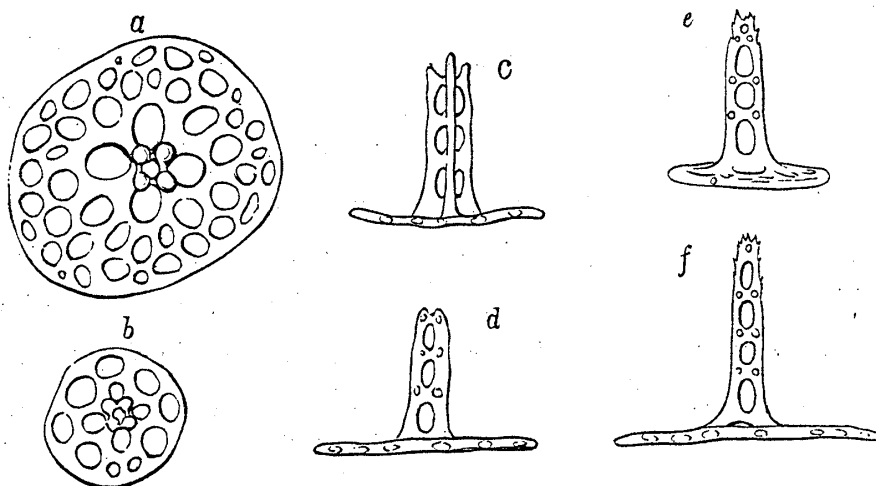
† As before, I am not speaking of the terminal discs and supporting rods of the tube-feet.

until in fully grown individuals, there are found nothing but small perforated plates, representing only a small central part of the basal disc and without any trace of the spire. These are moreover comparatively but thinly scattered in the skin.

As the changes outlined above take place only by degrees, it is not of course possible to fix any well marked stages; nevertheless as a matter of convenience in describing and identifying various steps in the changes, I have ventured to assort individuals in various stages of growth into five groups as follows:—

Stage I:—Includes the youngest individuals whose calcareous bodies are all well formed tables. The preparations* made from specimens

Fig. 2.



respectively 10, 18, 23, 27 and 30mm. long † present a striking appearance. The skin is so thickly crowded with tables that very little space is left between them. These tables (fig. 2) have all a well formed basal disc and a tall slender spire, and are tolerably uniform in size, compared with those found in later stages. The commonest size of the basal disc is about 0.06 mm. but exceptionally large ones may reach 0.11— or even 0.12 mm. when measured along the longer axis of those that

* Made by simply passing a piece of the thin and almost transparent skin through different grades of alcohol, clarifying it in clove-oil and then mounting it in balsam, without any treatment with potash.

† All measurements made in alcoholic specimens, unless otherwise specified.

have an oval disc. Those below 0.06 mm. are comparatively few, at least in the youngest individuals. They all possess a smooth margin. The four pillars of the spire are set very close to one another in the center of the disc. The commonest number of transverse beams are three or four, but exceptionally may become five or two. The pillars often incline towards one another, above the highest transverse beam but one, so that the spire frequently looks as if it were slightly conical or ended in a point. There are minute teeth on the spire, especially near the tip. The height of the spire is generally about 0.06 mm. but may become slightly higher (0.078) or lower (0.048).

In older individuals of this group—*e. g.* in those respectively 39, 40, 46, 50, 60 mm. long—the tables whose disc is less than 0.06 mm. sometimes becoming as small as 0.03 mm. are mixed with larger ones in a greater proportion than in younger individuals. Many of these discs have only eight holes *i. e.* four small holes in addition to, and alternating with, the four large holes at the center. Those with only the four central holes (fig. 3) which are such a prominent feature of later stages are as yet very rare, and even these have a tolerable spire. The height of the spire seems also in many cases somewhat reduced, and those with two transverse beams are of much more frequent occurrence. The tables are also much less closely scattered than heretofore. One individual 70 mm. long I feel justified in placing in this group, for although the features given above for the individuals that are 39–60 mm. long in contrast to younger individuals are brought out still more prominently, nearly all the tables have still some sort of spire, even if the spire has often only one transverse beam, or may consist of only three or two pillars.

We may therefore conclude that young individuals whose lengths are below about 70 mm. possess calcareous bodies which are all well formed tables.

It is evident that the specimens which VON MARENZELLER examined, belonged to this group, for the largest one in his possession measured 70 mm. This circumstance accounts for the fact that he makes no refer-

ence to those perforated plates or "Hemmungsbildungen" which others mention as an important feature.

Stage II:—In this group, I propose to include those individuals in which those small, perforated plates with or without rudiments of a spire (fig. 3) begin to be a noticeable feature but not to such an extent that they seem to form a larger portion of the calcareous deposits of the animal than the well formed tables. I have fixed a somewhat arbitrary standard and put in this group all those in whose skin I could count at least 7–10 well-built tables (fig. 2) in a field, when examined with Zeiss CC×3. The tables with 2–3 transverse beams are most frequent. Some with only one beam are seen.

It is impossible to fix any limits in the lengths of individuals belonging to this group with anything like accuracy. Those which I have placed in this group are respectively 50, 50.54, 70, 70, and 110 mm. in lengths.

I believe that the single specimen which THÉEL identified with some hesitation as *Stichopus japonicus*, belongs to this stage. His description tallies well with what I have given above.

Stage III:—This I propose to call the *typicus* stage, for those specimens which THÉEL distinguished as *Stichopus japonicus*, var. *typicus* may be taken as good examples of this stage. Here the calcareous bodies which correspond to the large well formed tables of the preceding stage have begun, many of them, to show various degrees of imperfection. This arresting of development affects both the basal disc and the spire. Thus the spire may become lower, have a smaller number of transverse beams (1–2), and often have the ends of the pillars bent outwards (SELENKA, Fig. 34, or THÉEL, pl. VIII, fig. 2*b*). Or the pillars may be reduced in number to three or two, or be occasionally increased to five (THÉEL, pl. VIII, fig. 2*d*), and often inclined towards one another, especially near the upper end so as to produce a conical shape. Or the spire may be represented by 1–4 simple knobs which are rudiments of the pillars. Or finally there may be no trace of a spire. The complete tables have the margin of their basal disc entirely smooth, but

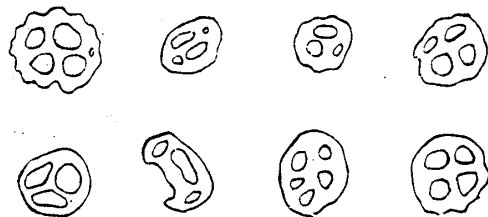
the discs that are affected by the "Hemmungsprozess" have all more or less spinous margin and are reduced in size in various degrees. (See THÉEL, Pl. VIII, Eig. 2*d*.) When no spire is developed a table becomes nothing but irregular perforated plates with spinous margin. The larger ones of this kind graduate by degree into small, perforated plates which we saw in the preceding stage. At this period, therefore, we see three kinds of calcareous deposits: (a) completely built tables such as we saw in Stage I, (b) tables showing various degrees of imperfection and having spinous margin, and (c) perforated plates, mostly with spinous margin which from tolerably large ones shade off into quite small quadriloculate forms.

The specimens which showed best the characteristics of this stage are several individuals 200–250 mm. long (in fresh state), which I obtained at Kanagawa and which I believe, from a series of observations made at the same locality, to be at the end of their first year. There are, however, others which are smaller (175 mm. fresh. Tōkyō market) and larger. THÉEL's specimens measured 220 mm. and must have been considerably larger in fresh state.

Stage IV:—This is the stage in which the original specimen described by SELENKA must have belonged, although it was only 110 mm. in length. The tables of the original form which were characteristic of Stage I, have now all disappeared or, if present, very rare, and only those that show various degrees of imperfection are seen and even these are not very numerous. The spire is mostly very low, having generally only one or at the most two transverse beams, and may be reduced in the number of the pillars. Various forms of asymmetry* may be produced by difference in lengths of the pillars on the same disc, or by the pillars inclining towards and fusing with, one another. SELENKA's Fig. 35 represents without question one of these forms, and I have seen many which are quite near it, although never one which is exactly as symmetrical as the one the figure shows. By far the most prominent feature

* Such forms may also be seen from earlier stages.

Fig. 3.



Some forms of perforated plates.
× 300.

of the calcareous deposits in individuals of this stage is the presence of those which SELENKA named "Hemmungsbildungen" (Fig. 3). These show various sizes, but on the whole are smaller than those in the *typicus* stage. On many are seen little knobs

which are the rudiments of the pillars of a spire.

It is impossible to give any limits in the lengths of individuals which belong to this stage. Those that I placed here range between 50 mm. (alcoholic specimen) and 210mm. (in fresh state). Probably still larger ones may be placed here.

Stage V.—This I propose to call the *armata* stage, for the specimen which SELENKA named *Holothuria armata*, had calcareous bodies which are typical of this stage. In other words, all forms of tables with a spire have now entirely disappeared. At the most, there are only simple knobs which represent the rudiments of the pillars of a spire. All the calcareous bodies are therefore in the shape of perforated plates or SELENKA'S "Hemmungsbildungen." In the younger ones of this stage, these perforated plates may be still large and have spinous margin, but the older the individual, the smaller and smoother become the calcareous bodies, and the nearer they approach the shape of a ring with *four openings*, representing the four central holes in the discs of the earlier tables. In the very oldest, even these four holes are not complete, and a part of the circumference may often be lacking to the ring. The calcareous deposits are also much more sparsely distributed than in earlier stages.

I need hardly remind the reader that as the above five stages have been artificially marked out in an unbroken series of changes, many an intermediate state of things will be found, which an investigator will find difficult to put precisely in any one of them. I claim for them nothing beyond some advantage that they afford in elucidating the

the process of changes in the calcareous deposits of *Stichopus japonicus*.

It is evident from what has been given above that the calcareous deposits in our species are more complete and show more primitive characters in young stages than in older or adult forms. In the youngest stages examined, they have almost the character of a calcareous coat of armor, similar to that of a starfish or of a sea-urchin. There are undoubtedly physiological reasons for this: the youngest individuals have a very thin and pliable skin and muscle layer so that some sort of protection and support is a necessity. But a possible phylogenetic significance should not be lost sight of.

It will be seen that I agree with THÉEL in regarding *Holothuria armata* of SELENKA to be only a form of *Stichopus japonicus*. My reasons for thinking so are as follows:—I have fortunately some specimens of *Holothuria armata* which Prof. SELENKA kindly identified for us during his stay in Japan. There can be therefore no question as to their being *Holothuria armata*. Now, an examination of the calcareous deposits of these specimens reveals a condition exactly like the fifth stage of *Stichopus japonicus*. I see no reason for separating them from other specimens of *Stichopus japonicus* of the same stage, so far as the calcareous deposits are concerned. Unfortunately, these specimens lack the viscera, and I have not yet had an opportunity of examining the reproductive organs of this type. But my friend, Mr. NOZAWA of the Hokkaido Fisheries Bureau informs me that when he examined some years ago the specimens of that form in order to determine its breeding season, he remembers seeing *two* genital bundles, one on each side of the median mesentery. There is therefore very little doubt in my own mind that the form which SELENKA has signalized as *Holothuria armata* is the northern form of *Stichopus japonicus*. It is easily distinguished by having four rows of many long pointed papillæ along the two dorsal ambulacra and the lateral margins, and by having numerous much smaller papillæ interspersed between these four rows. This form is found in the Hokkaido (Yesso) and the northernmost part of the Honshū (the main Island of Japan). As we go down southward in our country, the

papillæ of *Stichopus japonicus* seem to decrease in number as well as in height. This difference becomes so apparent when dried for the market that dealers in dried "namako" divide them into those with spines (papillæ) and those without them. The former is the northern form, while the latter from the southern part, show only a row of low papillæ along the lateral margins and few others scattered over the dorsal surface. Those from Tokyo and the vicinity seem to be intermediate between the two. I think that if the form found in the central part is taken as the type of the species, the northern form with many papillæ might be distinguished as *var. armatus*, while the southern form with few papillæ might be called *var. australis*. Of course, these pass into one another insensibly. And even at one and the same locality, there seems to be a great deal of difference in different individuals in this respect. I am inclined to think that the habitat of the animal has a great deal to do with the matter. Those that live among rocks along a rocky beach seem to be distinguished by a larger number of tall papillæ as well as by a mottled brown color, while those that live on sandy ground, probably among sea-weeds, have lower and fewer papillæ and have generally a dark green color. So that it seems possible to me to divide the species into varieties by latitude and by habitat.

It would be a singular fact, if the changes in the shape of the calcareous deposits brought out above in *Stichopus japonicus* should turn out to be the solitary case of such an occurrence among the order of Holothurioidea. I am rather inclined to think that if carefully studied, every species will present more or less similar changes. If this should turn out to be the case, I need hardly point out what an important bearing it has on the systematic classification of the species of holothurioidea. At any rate, those who collect holothurians should bear the fact in mind and endeavor to obtain a large number of individuals in various stages of growth from different localities.

Science College, Imp., Univ., Tokyo.